1906

Furnace calculations

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THESIS

FOR THE

Degree of Bachelor of Science

IN

MINE ENGINEERING.

SUBJECT:

"Furnace Calculations."

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JUNE, 1906.

F U R N A C E C A L C U L A T I O N S .

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PROBLEM.

A furnace that will smelt a given amount of material per twenty-four hours, to dimension parts, and finally draw the complete plans. Copper Matting Furnace.

(1) Smelt say ninety tons in twenty-four hours. Should smelt this in, say, four charges per twenty-four hours. Of this take four and one-half hours to smelt each charge, and one and one-half hours to skim and charge, and fix up bed of fuel.

(2) Fuel to be bituminous coal, direct fired.

Ash	15 %
Fix C.	44.5 %
Vol Matter	40 %

Heat about 8,000 calories = 8,000 pound calories.

(3) In ordinary practice in work similar to this, they use 3.5 tons of charge per one ton of coal. Compute the theoretical amount of heat generated by such coal as is used, then the actual amount of heat required to

bring material to a slag and matte at, say, 1000° C. by reactions. This will involve classifying your slag, figuring formation heats of silicates, reduction of Fe_2O_3 to FeO, etc., for the various reactions.

From this get an idea of coal efficiency. This efficiency will then serve as a guide in your own calculations.

Slag made was:

34.5 % SiO_2
43. % FeO (MuO)
8.5 % Al_2O_3
14.0 % ZnO
0.6 % Cu
1.0 oz Ag
3.56 = Spgr

Matte made was:

50.0 % Cu
4.8 = Spgr
100 ozs Ag.

This matte is 8% higher than the actual per cent S. in the roasted ore would theoretically call for.

Common practice in smelting, in burning fuel, shows about twice as much air drawn through the grate as is theoretically required to burn the coal.

Calculate this amount with coal consumption, calculate the total heat generated at the rate of combustion of your coal, and the pyrometric effect as nearly as possible. Will have to assume that the products of combustion

Design furnace, using fire and red brick in the proper places.

Ref. (See Ingall's Heating and Furnace Design.)

Classification of Slag:

$2Al_2O_3 \cdot 3SiO_2$ = mono-silicate of aluminum.

$$\frac{2Al_2O_3}{3SiO_2} = \frac{8.5}{X} = \frac{(27 \times 2 + 16 \times 3)2}{3 \times 60} = \frac{204}{180}$$

X = 7.5# SiO_2 required to form mono-silicate of aluminum.

Slag Analysis:

34.5 % SiO_2

43.0 % FeO

8.5 % Al_2O_3

14.0 % ZnO
0.6 % Cu
1.0 oz Ag

3.56 = Spgr 2 ZnO . SiO_2 = Mono-silicate.

$$\frac{2ZnO}{SiO_2} = \frac{14}{X} = \frac{162.8}{60}$$

$162.8X = 840$

X = 5.16# SiO_2 required to form $2ZnO.SiO_2$ with the 14# Zno in slag.

7.5
5.16
12.66# SiO_2 required for Al_2O_3 and Zno

34.50# SiO_2 = total in slag per 100#
21.84# SiO_2 remains, therefore to combine with iron.

2 FeO . SiO_2 = mono-silicate of iron

FeO . SiO_2 = bi-silicate of iron

2 FeO . $3SiO_2$ = sesqui-silicate of iron

2 FeO . SiO_2 = proto- or sub-silicate of iron.

$$\frac{2.FeO}{SiO_2} = \frac{144}{60} = \frac{43}{X}$$

$144X = 2580$

$X = 18$ Kgm SiO_2 required for 43 Kgm FeO as mono-silicate.

For bi-silicate would have:

$$\frac{FeO}{SiO_2} = \frac{43}{X} = \frac{72}{60}$$

$X = 35.8$ Kgm SiO_2 to form bi-silicate.

Sesqui-silicate would require 26.9 Kgm SiO_2. Have only 21.8 Kgm SiO_2, so approximates more closely the mono-silicate than any other, but lays between the mono- and sesqui-silicates.

If, therefore, 10 Kgm FeO goes to form the bi-silicate, and the other 33 Kgms remaining goes to form a mono-silicate, there will be required 22.0 Kgm SiO_2. Assuming then, that a certain amount of the FeO and SiO_2 have combined to form the bi-silicate, and the rest forms a mono-silicate in which the bi-silicate remains

in solution, analagous to CO and CO_2 in furnace gases, or SO_2 and SO_3 in roaster gases, we have the following disposition of material:

Al_2O_3	9.5 Kgm;	SiO_2	7.5 Kgm	Mono-silicate
ZnO	14.0 Kgm;	SiO_2	5.16 Kgm	Mono-silicate
FeO43	33.0 Kgm;	SiO_2	13.7 Kgm	Mono-silicate
FeO43	10.0 Kgm;	SiO_2	2.3 Kgm	Bi-silicate
			34.66	
			34.5 Kgm	SiO_2 present
			.16 Kgm	SiO_2 more than

actually have, or 33.3% FeO forms bi-silicate, and 76.6% FeO goes to form mono-silicate.

537# FeO forms bi-silicate = 230. Kgm

1743# FeO forms singulo-silicate = 790.6 Kgm.

Size of Grate in Problem:

Ninety tons in forty charges, or two hundred and twenty-five tons per charge requires about one ton of coal per thirty-five tons of charge, so $\frac{225}{35}$ = 6.43 tons of coal per charge. Four charges per twenty-four hours regular running, or $\frac{6.43}{6}$ = 1.07 tons of coal per hour = 2140# per hour. Allowing 20# per square foot per hour grate area = 107 ' or grate is 8'-0" X 13'-5"

According to Kent, 10# per square foot per hour gives the most efficient results, and as high temperature

can be obtained, common practice runs much higher, however, and 40# is not an uncommon figure in boiler practice.

This is entirely too rapid combustion for the reverberatory furnace, and in fact an entirely different result is the object.

In reverberatory practice a long flame is desired, and but little actual burning in the grate. The flame and products of combustion and distillation of the coal, pass over the fire bed in a rather cramped condition, and develop in the laboratory of the furnace, and it is there that complete combustion takes place, and the intense heat of the flame develops.

In order ~~xkx~~ to accomplish this, and obtain a long flame, it is necessary to use an extremely thick bed of fuel, and to have only partial combustion taking place in the fire box. In fact the length of the flame is directly proportioned to the thickness of the bed of fuel. For this reason the grate area is diminished to 5'-0" X 8'-0", and a thicker bed of fuel is used.

In gas with no visible smoke, and what is considered good and complete burning, have 2.5% CO.

Each Kgm carbon requires 2.66 Kgm O to burn to CO_2.

Each Kgm carbon requires 1.33 Kgm O to burn to CO.

Each Kgm H requires 8 Kgm O to burn to H_2O.

The coal used in firing this furnace has approximately the following analysis:

Coal Analysis:

Mais	3.00%
H_2O (Comb)	12.50%
Fix Carbon	44.50%
H	4.50%
C	19.60%
Ash	13.50% plus 15% of the above

Fix Carbon, which goes into ash, so available carbon is 43.00%, while total ash is 15%.

Ash Analysis:

		corrected for 10% carbon
SiO_2	44.15%	39.66
Fe_2O_3	16.60	14.90
Al_2O_3	37.90	34.14
CaO	1.00	0.90
MgO	0.40	0.36
S	0.04	.04
	100.09	Carbon 10.00

and this gives, per one hundred pounds of coal consumed, the following weights of substances going

into ash, and carrying heat from the furnace:

Material in ash per one hundred pounds of coal comsumed:

SiO_2	8.00#
Fe_2O_3	.50
Al_2O_3	5.10
CaC	.14
MgO	.05
S	.01
Carbon	1.50
	15.00

Matte = 50% Cu, and is 9% higher than the outcome expected. (See condition of problem)

The raw ore is concentrates carrying

15% Cu

10% SiO_2

The best recovery obtainable is about 95% Cu, and 5% is rational figure for slag loss.

Have a concentration then of

$$\frac{50}{15 - \text{loss in slag}} = \frac{50}{15 - (.05 \times 15)} = 3.64 \text{ cons.}$$

That is to say, 3.64 tons of raw material are put into one ton of matte, or the values, etc., from that amount of raw ore.

Calculating back, then we have in raw ore from the matte

1000 - (6X8) + 31.7# = 933.7# Cu.

31.7# comes from 3.64 tons .006 equal total Cu in raw ore.

This Cu will require sulphur to the extent of

$$\frac{Cu_2S}{5} = \frac{127.66}{32} = \frac{1000-40}{5} \qquad S = 240\#$$

The rest of the matte will be made up of iron and sulphur. That is to say,

$$\frac{952}{50} = 1904\# \text{ matte}$$

952 = Cu

240 = S

1192

1904 - 1192 = 712# FeS in matte

FeS = $\frac{56}{88}$ = 63.63% Fe

So 712 X 63.63 = 453# Fe and leaves 712 - 453 = 259# S in matte. Also 40.3# S more than calculated upon is volatalized so we get 50% matte rather than 42% matte.

Now this Fe will be in original ore as Fe_2O_3 and equal $\frac{112 + 48}{112}$ X 453 = 647.1# Fe_2O_3

From the slag we have the following

ZnO = 14% X 2.64 X 2000 = 739.2#

Al_2O_3 = 8.5% = 160.0#

SiO_2 = 10% in con. = 532.0#

= 24.5% from fettling = 1293.6#

FeO = 43% = 2270.4# = Fe_2O_3 to 2454.5#

all of which give a total weight of 7346.4# for the original charge.

Original Charge:

Cu	953.7#	953.7#	
S for Cu	240#		from matte
S for Fe	259#		
Volatalized	40.3#	539.3#	
Fe_2O_3 from 453# Fe		647.1#	

Fe_2O_3 from 2070.4# FeO	=	2454.5#	)
ZnO unchanged	=	730.9#	) From blag
Al_2O_3 "	=	160.0#	)
SiO_2 "	=	500.0#	)
SiO_2 from furnace fettling	=	1903.6#	From 24.6% not accounted for in original ore.
		7546.4#	

Cu	983.7 X .4536	=	446.3	kilograms
Fe	453. 1764. X .4536	=	1005.6	"
S	490.0 X .4536	=	222.0	"
Zn	593. X .4536	=	269.0	"
Al	84.7 X .4536	=	38.4	"
Si	850.2 506. X .4536	=	385.7	"
O	971.0 X .4536	=	770.4	"

Combustion of the Coal:

1 Kilogram of coal in furring gives the following:

.43 Kgm Fix Carbon and

.196 Kgm Vol Carbon

.626 Kg Carbon

So .626 X $\frac{97200}{12}$ = 5071 calories Co_c .045 Kgm H_2O

.045 X $\frac{69000}{2}$ = $\frac{1553}{6624}$ calories H_2O calories total

Now, in burning twelve kilograms of carbon, combine with thrity-two kilograms of oxygen to form 22.22 cubic meters of Co_2, and for each kilogram C, 2.67 kilograms O, are required, so have:

.626 X 2.67 = 1.67 Kgm O for the C, and for H have:

.045 X 8 = .360 Kgm O, for the hydrogen

Total 2.03 Kgm O actually required.

Now it is good practice and ordinary, to use about 25% excess O in reverberatory, while in steam boiler practice, and other places where a thin bed of fuel is used, 100% excess is used. In this case, however, can keep it down to 25%. This gives total oxygen of 2.03 X 125 = 2.54 Kgm O.

Volume of Gases and Temperature:

32 Kgm O = 22.22 M^3. So

C. $\frac{254}{32}$ X 22.22 = 1.76 cubic meters of O.

Air. and $\frac{1.76}{20.8}$ X 100 = 8.46 cubic meters of air; air being 20.8 % oxygen.

N. 8.46 - 1.76 = 6.70 cubic meters nitrogen

For Co_2 have:

CO_2 $\frac{1.68 + .626}{44}$ X 22.22 = 1.165

Free O. 1.76 - 1.16 = .60 cubic meters of O.

H_2O have (.045 X 9 + .039 + .126) X $\frac{22.22}{18}$ = .7033

Then 6624 = (0.303 t + .000027 t^2) (6.70 + .60) +

+(0.37 t + 00022 t^2) (1.165) +

+(0.34 t + 00015 t^2) (.7033) +

$$6624 = \begin{cases} 2.2119\ t + .0001971\ t^2 \\ 0.4311\ t + .0002563\ t^2 \\ 0.2391\ t + .0001055\ t^2 \end{cases}$$

$$6624 = 2.8821\ t + .0005589\ t^2$$

$$11851051.85 = 5157.\ t + t^2$$

$$t^2 + 5157\ t + (2578)^2 = 11851051.85 + (2578)^2$$

$$t = -2578 \pm \sqrt{11351351.85 + 6646000}$$

$$t = -2578 + 4300.9 = 1722^{9}\ C.$$

Burn 2140# coal per hour =

2140X.4536 = 971. Kilograms per hour, or

16.2 Kilograms coal per minute.

Now, in ~~burning~~ burning one kilogram of coal have:

6.700 cubic meters N_2

0.600 " " O_2

1.165 " " CO_2

0.703 " " H_2O

9.168 " " Gas, or for 16.2 kilograms have 16.2 X 9.168 = 148.52 cubic meters of gas at ordinary temperature, passing through furnace per minute.

Below is temperature curve and volume curve for furnace, beginning four feet from fire bridge.

(See next page)

Volume in Cubic Meters
5 6 7 8 9 10 11 12 13 14 15 16 17 18
TEMPERATURE IN DEGREES CENT.
At Fire Bridge and for 4'→ 1723°C
Temperature Curve in °C.
1000° C Gases Leave Furnace.
Volume Curve - Cubic Meters.
1 2 3 4 5 6 7 8 9 10
DISTANCE IN TENTHS OF HEARTH LENGTH
Volume in Cu.M.
5 6 7 8 9 10 11 12 13 14 15 16 17 18
TEMPERATURE IN DEGREES CENT.

Sp gr of gases: (Air = 1)

6.7	N_2	X .971	=	6.5057
0.6	O_2	X 1,105	=	.6630
1.165	CO_2	X 1,529	=	1.7813
0.703	H_2O	X 0.992	=	.6974
9.168				9.6474

9.168 | 1.052 = Density of gases with air = 1

47940

45840

21000

$$h_o = 23\left(\frac{\left(1 - 1.05 + \frac{1}{273}\left(\frac{1000 + 400}{2}\right)\right) = 1.05 \times 15}{\left(\left(1 + \frac{1}{273} \times 15\right)\left(1 + \frac{1}{273} \times \frac{1000 + 400}{2}\right)\right)}\right)$$

h_o = 15.010 meters from

$$h = H\left(\frac{1 - o\ \frac{1}{273}(t - Dt')}{\left(1 + \frac{1}{273}t'\right)\left(1 + \frac{1}{273}t\right)}\right)$$

In which:

H = Height of chimney in meters = 23

D = Sp gr of gases (air = 1) = 1.052

t = temperature in chimney = $\frac{1000 + 400}{2}$ = 700° C.

t' = temperature of outside air = 15° C.

h = total head in meters of air of 0° C.

Now the gases have velocity of three meters per second

(good practice), and the head required to give this is $h = \frac{3^2}{196} = .46$ m in terms of hot gas (700°C), or in terms of gas at 0° C $= 0.46 \times \frac{273}{400+273} = 1.06$ meters. For a velocity of three meters per second a diameter, d, will be required of

$$3 = \frac{\frac{148.52}{500}}{\frac{\pi d^2}{4}} = \frac{4 \times 7 \times 2.475}{22 d^2} = 1.05 \text{ m}$$

$$d = \sqrt{1.05} = 1.02 \text{ meters in diam.} = 3.3 \text{ ft.}$$

$$\text{Lost head due to friction} = h = .186 \times \frac{23}{1.02} \times .08$$

$$h \text{ friction} = 0.34 \text{ meters}$$

Which gives an effective head of 15.02 - (.19 + .34) = 14.5 meters = 44.08 ft.

44.08 ft air = .0571 ft water = .025# = 0.6852 inches of water.

Total Volume of Cases:

$$\text{At fire bridge or 4' from same} = 148.52 \times \frac{1723+273}{273} \times \frac{273}{273+15} \times \frac{14.7 - .025}{14.7} = 1027.$$

$$\text{At 1/10th point} = 148.52 \times \frac{1650+273}{273} \times \frac{273}{273+15} \times \frac{14.7 - .025}{14.7} = 1013.$$

$$\text{at 2/10th point} = 148.52 \times \frac{1580+273}{273} \times \frac{273}{273+15} \times \frac{14.7 - .025}{14.7} = 953.$$

$$\text{At 3/10th point} = 148.52 \times \frac{1510+273}{273} \times \frac{273}{273+15} \times \frac{14.7 - .025}{14.7} = 917.$$

$$\text{At 4/10th point} = 148.52 \times \frac{1435+273}{273} \times \frac{273}{273+15} \times \frac{14.7 - .025}{14.7} = 870.$$

$$\text{At 5/10th point} = 148.52 \times \frac{1360+273}{273} \times \frac{273}{273+15} \times \frac{14.7 - .025}{14.7} = 840.$$

$$\text{At 6/10th point} = 148.52 \times \frac{1290+273}{273} \times \frac{273}{273+15} \times \frac{14.7 - .025}{14.7} = 804.$$

$$\text{At 7/10th point} = 148.52 \times \frac{1220+273}{273} \times \frac{273}{273+15} \times \frac{14.7 - .025}{14.7} = 768.$$

$$\text{At 8/10th point} = 148.52 \times \frac{1145+273}{273} \times \frac{273}{273+15} \times \frac{14.7 - .025}{14.7} = 727.$$

$$\text{At 9/10th point} = 148.52 \times \frac{1075+273}{273} \times \frac{273}{273+15} \times \frac{14.7 - .025}{14.7} = 693.$$

$$\text{At exit point} = 140.52 \times \frac{1000+273}{273} \times \frac{273}{273+15} \times \frac{14.7 - .026}{14.7} = 650.2$$

Taking volume of exit point, and calculating from this the volumes at other points in per cent, we have inverse percentage curve shown in diagram on previous page. Also taking the volume at fire bridge, and calculating the relative volumes at different stages throughout furnace, we have the percentage curve shown on diagram.

Heat Required:

Fe_2O_3 to FeO

$$2454.5\# \times .4536 = 1112.36 \text{ Kgm } Fe_2O_3$$

$$(135600 - 266700)\frac{1112.36}{112} = -637004.75 \text{ calories}$$

Fe_2O_3 to Fe

$$453\# \times 0.4536 = 205.4 \text{ Kgm } Fe_2O_3$$

$$205.4 \times \frac{135600}{112} = \frac{-350716.4}{-286321.15 \text{ calories}}$$

Sources of Heat:

C $\quad 40.3\# \text{ C} \times .4536 = 18.28$ calories

$$18.28 \times \frac{69,200}{32} = +39470.20 \text{ calories}$$

$FeO_2(SiO_2)$ $2270\#$ FeO = 1029.7 Kgm FeO

Of this 258.9 Kgm goes to form a bi-silicate, while the remaining 770.8 Kgm go to form a singulo-silicate. There-

fore

$$230.9 \times \frac{(254.000 - (65700 + 180000)}{56 \qquad 4} = 37046.25 \text{ calories}$$

$$\text{and } 790.9 \times \frac{(320400 - (2 \times 65700 + 180000)}{112} = 63562.50 \text{ "}$$

Total heat 140087.0 Calories

So 996321.15 - 140087.0 calories = heat required to be furnished by burning coal = 855334.15 calories

plus heat from following = 729956.60 "

1585290.75

1223.7# Cu_2S = 555.1 Kgm

Besides the heat required for the reduction of Fe_2O_3 and to FeO and Fe, there will be required heat to melt down the charge and maintain it in molten condition to cause the necessary reactions to take place, or to make them possible, etc. These amounts are estimated below:

Cu_2S

Heat in 1 Kgm Cu_2S at temperature of furnace 1000° is - 202.6 calories

Heat in 1 Kgm Cu_2S at 15°C 1.7 "

Heat required to bring 1 Kgm Cu_2S to 1000° 200.9 "

Latent heat of fusion, by 2.1 T Rule 14.3 calories

Total heat to bring 1 Kgm of Cu_2S to 1000°C = 215.2 "

Heat required for 555.1 Kgm = 119 457.5 "

FeS.

Heat in 1 Kgm FeS at 1000°C =

1000 (.1357 + .000025 X 1000) 1.0 = 160.7 calories

Heat in 1 Kgm 15° C is

15(.1357 + .000025 X 15)1.0 = 2#04 "

Heat required to bring 1 Kgm FeS to 1000°= _____

158.66 "

Latent heat of fusion

$\frac{2.1\ (800+275)}{56+32}$ = 25.61 "

Heat 1 Kgm = 184.27 "

Total heat required to bring 712# FeS

to 1000° = 712 X .4536 = 322.96 Kgm

323 x184.2 = 59528.9 calories

Mono-silicate of Iron $(FeO)_2(SiO_2)$

Heat required to bring 1 Kgm to 1000 °C = 310 calories

(See Vogt and Richards)

Heat in 1 Kgm at 15°C = 15(.1700 + .00004 x 15) = 2.6 "

307.4 "

Latent heat of fusion (Vogt) = 25.0 "

Total heat per Kgm at 1000° C = 332.4 "

Total heat for 700.6 Kgm = 302.4 X 700.6 = 310931.4 calories

Bi-silicates:

Heat required to bring 1 Kgm to 1000°C =

1000(.1646 + .00037 X 1000)1.0= 554.6 calories

Heat 1 Kgm at 15°C = 15(1646 + .0004 X 15)1.0= 2.6

Heat required to bring 1 Kgm to 1000°C= 552.0 "

55° X .25 (See Vogt's rule) L.H.F. = 138.0 "

Heat required to bring 1 Kgm to 1000°C= 690.0 "

Total heat required for 230 Kgm = 690 X 230= 164910.0 "

Note:

The foregoing results are slightly higher than those obtained by Akerman on furnace slags, though direct comparison is impossible, as his slags differ somewhat in composition from these.

ZnO.

Heat required to raise 1 Kgm to 1000°C is

1000(.0906 X .000044 X 1000)1.0 = 134.6 calories

Heat in 1 Kgm at 15°C = 15(.0906 X .000044 X 15)= 1.4 "

Latent heat of fusion, 133.2 "

according to Vogt = 73.3 "
(By 2.1 T rule = 30.0 calories)

Heat required to bring 1 Kgm to 1000°C = 166.5 calories

Total heat for 335.3 Kgm = 335.3 X 166.5 = 55827.5 calories

Al_2O_3

Heat required to bring 1 Kgm to 1000°C is

1000(0.2081 +.00005 X 1000)1.0 = 258.1 calories

Sensible heat at 15°C = 15(0.2081+.00005

X 15) X 1.0 = 4.7 "

Latent heat of fusion by 2.1 T rule

$\frac{2.1 \times (800+273)}{2 \times 27+3 \times 16} = 22.1$ = 22.1 "

Total heat required for 72.6 Kgm

72.6 X 275.5 = 20001.3 "

Total heat required then is

Aluminum compounds	220001.3	"
Zinc "	55827.5	"
Fe, bi-silicate	164010.0	"
Mono-silicate	310231.4	"
Sulphide	50528.0	"
Cu Sulphide	110457.5	"
For reduction of Fe_2O_3 to Fe	358710.4	"
For reduction of Fe_2O_3 to FeO	637604.8	"
Total	1736877.8	"

One kilogram of coal, upon burning, gives up 6624 calories. Have 671 Kgm coal burning per hour for four and one-half hours of actual smelting, or 4369 Kgm coal burning while charge is smelting down, and this gives:

4369 X 6624 = 28940256 calories

Also have heat derived from oxidization of sulphur (See page 21) = 39478.2 calories

and from formation of silicate (See page 21) = 101508.75 calories

Total heat from everything = 29081243 calories

Then efficiency of furnace E is:

$$E = \frac{1726277.2}{29081243.0} = 5.4\% \text{ Efficiency.}$$

Sp gr of matte = 4.8

Ten tons of matte required to be kept in furnace to protect the bottom = 20000#

One cubic foot weighs 4.8 X 62.5 = 300#

Volume of ten tons matte = $\frac{20000}{300}$ = 67 cubic feet.

The taper with which the furnace widens from the fire bridge to the full width of the laboratory, was increased materially over that at which it tapers in at the flue end. The idea here is to take advantage of the partial vacuum which would be formed, together with the eddy currents, to produce more rapid development of the flame from its cramped condition, as it leaves the grate

and passes over the fire bridge, thus it approaches more nearly the theoretical values calculated for it, and the intense heat which it is capable of developing is realized in the early part of its progress toward the exit flue. This allows a greater temperature face within the furnace itself, and for a given length of furnace more efficient use of fuel; or in original design mitigates the necessity of extreme lengths.

The fire bridge is of the hollow type, and air is admitted through the bridge into the furnace laboratory, protecting the bridge, and insuring more complete combustion.

The rise of the arch for the first one-half of the furnace length, is one in eight, while at the lower end of the furnace it has diminished to one in twelve. This has been found to give satisfactory results, and is common practice, so is adhered to here.

Two expansion areas are included in both sides and roof of furnace, the details of which are shown in the general drawing. Other dimensions, etc., are shown on General drawing, and are self-explanatory.